fMRI and MRI at NIH

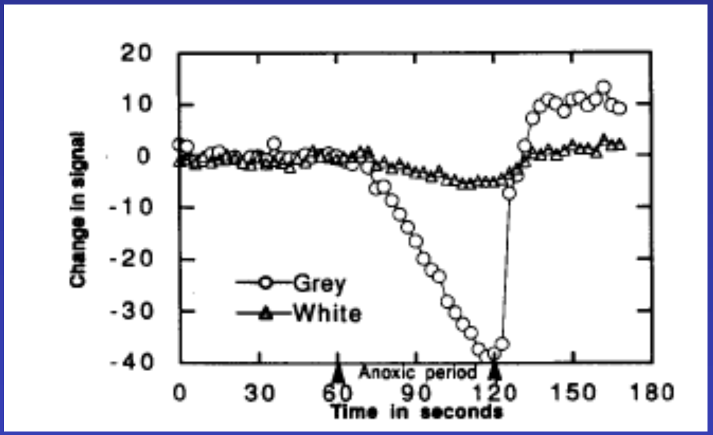
Sean Marrett / FMRIF / NIMH

MRI and Brain MRI at NIH

1. Development of MRI at NIH
    - In-Vivo NMR Center (established 1986ish)
        - 2 Bruker animal magnets, GE Signa 1.5T
        - 4 Tesla with head gradient (NHLBI 1989ish)
2. Early BOLD studies in animals
3. Initial human functional studies (1993ish)
4. Key developments from NIH and MRI researchers now at NIH
    - DTI
    - Magnetization Transfer
    - Population-based longitudinal studies of brain development
    - Imaging genomics
    - FMRI
    - Perfusion imaging (Arterial Spin Labeling)
    - Decoding/Multivoxel Pattern Analysis
    - High resolution anatomical imaging
    - Real-time FMRI / Analysis Software
    - High-field imaging (4 Tesla, 7 Tesla)

Early BOLD MR Measurements in Animals

Turner R, Le Bihan D, Moonen CT, Despres D, Frank J "Echo-planar time course MRI of cat brain oxygenation changes" Magn Reson Med. 1991 Nov;22(1):159-66



Early FMRI in Humans

Functional Mapping of the Human Visual Cortex at 4 and 1.5 Tesla Using Deoxygenation Contrast EPI

R. Turner, P. Jezzard, H. Wen, K. K. Kwong, D. Le Bihan, T. Zeffiro, R. S. Balaban

The effects of photic stimulation on the visual cortex of human brain were studied by means of gradient-echo echo-planar imaging (EPI). Whole-body 4 and 1.5 T MRI systems, equipped with a small *z* axis head gradient coil,
image intensity of up to 28% at 4 T, an
observed in primary visual cortex, c
crease of blood oxygenation in regi
activity. The larger effects at 4 T ar
importance of the susceptibility diff
genated and oxygenated blood at hig

blood flow than in oxygen utilization during somatosensory stimulation. Similar results were reported in cat brain during electrical stimulation by Lübbers and Leni-

agnetic fields the effect of sus-
eightened, it was of interest to
changes due to photic stimula-
using our 4 T whole-body MR
nparison, EPI experiments at 4

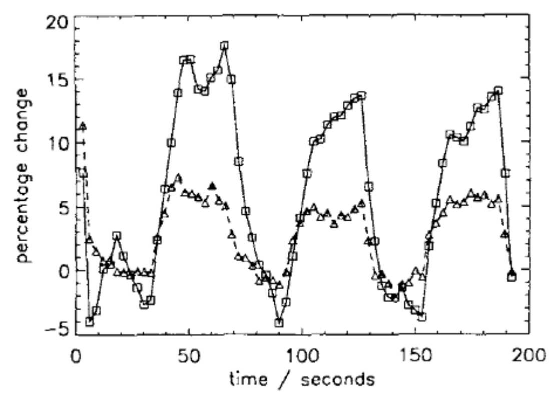


FIG. 2. Plot of fractional change in 4 T (squares) and 1.5 T (triangles) EPI image intensity versus time in the eight-voxel regions of interest in the visual cortex shown in Fig. 1, for a volunteer experiencing alternate 30-s periods of rest and photic stimulation. Details of acquisition for the 4 and 1.5 T data are described in the caption for Fig. 1.

Invention of DTI

Biophysical Journal Volume 66 January 1994 259–267

MR Diffusion *Tensor* Spectroscopy and Imaging

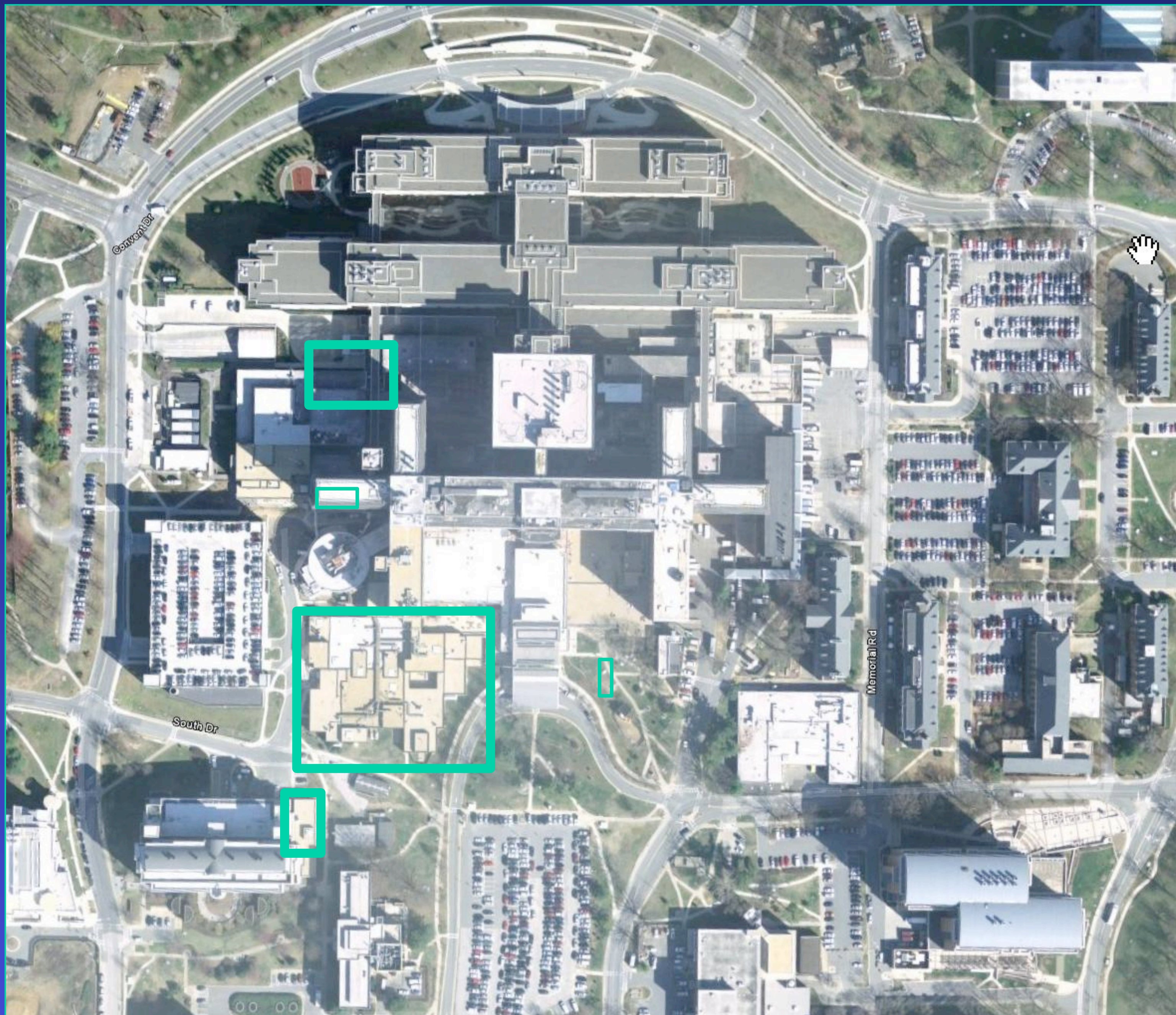
Peter J. Basser,* James Mattiello,* and Denis LeBihan‡

*Biomedical Engineering and Instrumentation Program, National Center for Research Resources, and ‡Diagnostic Radiology Department, The Warren G. Magnuson Clinical Center, National Institutes of Health, Bethesda, Maryland 20892 USA

ABSTRACT This paper describes a new NMR imaging modality—MR diffusion *tensor* imaging. It consists of estimating an effective diffusion tensor, $\mathbf{D}_{\mathrm{eff}}$, within a voxel, and then displaying useful quantities derived from it. We show how the phenomenon of anisotropic diffusion of water (or metabolites) in anisotropic tissues, measured noninvasively by these NMR methods, is exploited to determine fiber tract orientation and mean particle displacements. Once $\mathbf{D}_{\mathrm{eff}}$ is estimated from a series of NMR pulsed-gradient, spin-echo experiments, a tissue's three orthotropic axes can be determined. They coincide with the eigenvectors of $\mathbf{D}_{\mathrm{eff}}$, while the effective diffusivities along these orthotropic directions are the eigenvalues of $\mathbf{D}_{\mathrm{eff}}$. Diffusion ellipsoids, constructed in each voxel from $\mathbf{D}_{\mathrm{eff}}$, depict both these orthotropic axes and the mean diffusion distances in these directions. Moreover, the three scalar invariants of $\mathbf{D}_{\mathrm{eff}}$, which are independent of the tissue's orientation in the laboratory frame of reference, reveal useful information about molecular mobility reflective of local microstructure and anatomy. Inherently, tensors (like $\mathbf{D}_{\mathrm{eff}}$) describing transport processes in anisotropic media contain new information *within a macroscopic voxel* that scalars (such as the apparent diffusivity, proton density, T_1, and T_2) do not.

Where is MRI At NIH - Human

1. NIH MRI Research Facility (NMRF)
    - 3T GE HDx
2. FMRIF (NIMH & NINDS)
    - 3 x 3T GE HDx
    - 1 x 1.5T GE HDx
    - (in preparation - 2010) 7T Siemens/Magnex
    - (in preparation - 2011) 3T Siemens (Skyra)
3. NINDS/NIMH
    - 7T GE HD
    - (in preparation – 2011) 11.7T Siemens/Magnex
4. NINDS (Stroke)
    - Suburban Hospital
    - Washington Hospital
5. Clinical Center (Radiology & Imaging Sciences, TBI)
    - 3T & 1.5T Philips & 3T Siemens
6. NHLBI (Cardiac Energetics, Cardiovascular Intervention)
    - Mulitple 1.5T Siemens Scanners
7. NCI/CCR – Molecular Imaging Program (also at Ft. Dietrich)


Convent Dr
South Dr
Memorial Rd

NIH NMR Facility

Where is fMRI at NIH - Human

1. NIH MRI Research Facility (NMRF)
   - 3T GE HDx
2. FMRIF (NIMH & NINDS)
   - 3 x 3T GE HDx
   - 1 x 1.5T GE HDx
   - (in preparation - 2010) 7T Siemens/Magnex
   - (in preparation - 2011) 3T Siemens (Skyra)
3. NINDS/NIMH
   - 7T GE HD
   - (in preparation – 2011) 11.7T Siemens/Magnex

In-Vivo NMR Center Magnets

Where is fMRI at NIH (dedicated animal)

1. NIH MRI Research Facility (NMRF) & Mouse Imaging Facility
   - Multiple small animal magnets (4.7T, 7T Bruker)
2. Neurophysiology Imaging Facility (NIMH/NINDS/NEI)
   - dedicated 4.7T vertical bore primate
3. LFMI/NINDS
   - 7T Bruker (marmoset)
   - 11.7T Bruker (rodent, small animal)
4. NCI-Frederick Small Animal Imaging Program
   - 3T Philips

fMRI research + resources at the NIH

Studies focusing on:

- Normal Brain Function
- Mental disorders
  - Schizophrenia
  - Mood disorders
  - ADHD
  - Autism
  - Williams syndrome
  - Psychosis
  - …

Within FMRIF 7 human MRI scanners (1 - 1.5T, 5 - 3T, 1 - 7T)

MEG, EEG

3 dedicated animal MRI scanners

Micro CT, Ultrasound, Bioluminescence

Ongoing FMRI Studies

- Epilepsy
- Visual processing
- Mood disorders
- Learning
- Schizophrenia/Imaging Genetics
- Plasticity/Recovery
- Motor Function
- Auditory processing
- Attention
- Language
- Speech
- Stroke
- Social Interaction
- Development
- Decision making

Users

NIMH:
Peter Bandettini, Ph.D.
Chris Baker, Ph.D.
Karen Berman, M.D.
James Blair, Ph.D.
Jay Giedd, M.D.
Christian Grillon, Ph.D.
Wayne Drevets, M.D.
Ellen Liebenluft, M.D.
Alex Martin, Ph.D
Husseini Manji, M.D.
Andreas Meyer-Lindenberg, M.D.
Mort Mishkin, Ph.D
Elizabeth Murray, Ph.D
Daniel Pine, M.D.
Judith Rapaport, M.D.
Jun Shen, Ph.D.
Susan Swedo, M.D.
Leslie Ungerleider, Ph.D.
Daniel Weinberger, M.D.

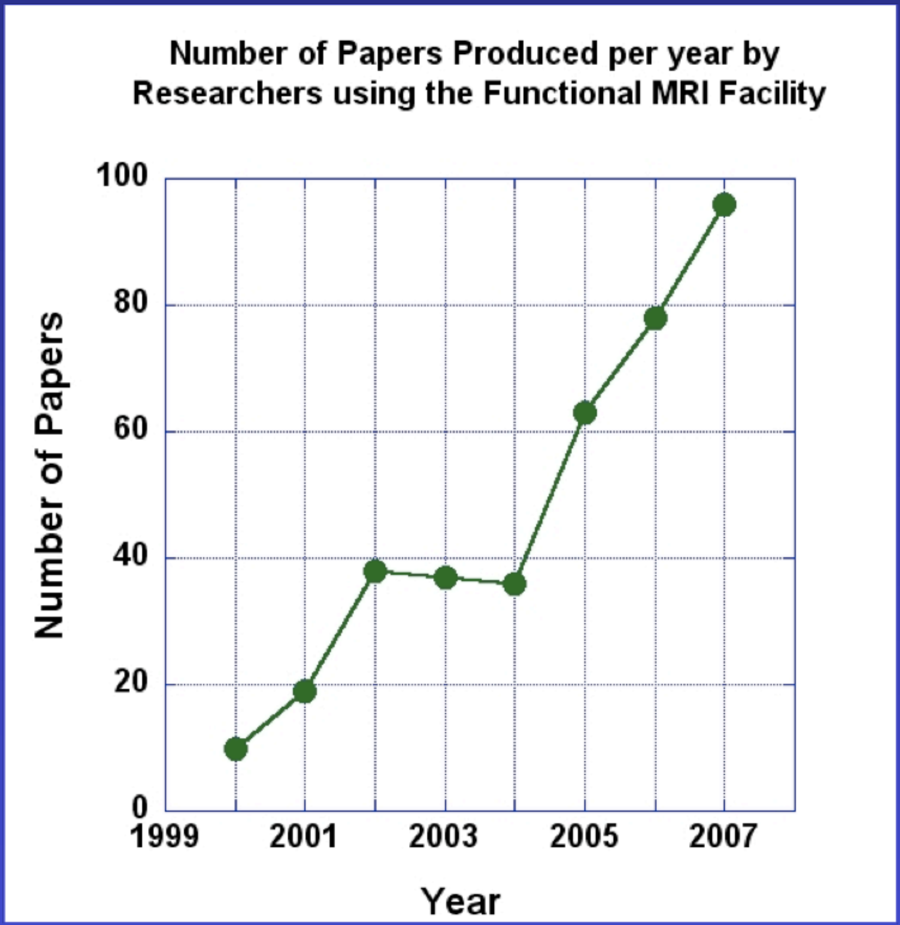
NINDS:
Leonardo Cohen, M.D.
Jeff Duyn, Ph.D.
Jordan Grafman, Ph.D.
Mark Hallet, Ph.D.
John Hallenbeck, M.D.
Alan Koretsky, Ph.D.
Edward Oldfield, M.D.
Danny Reich, M.D., Ph.D.
William Theodore, M.D.

NIAAA:
Daniel Hommer, M.D.

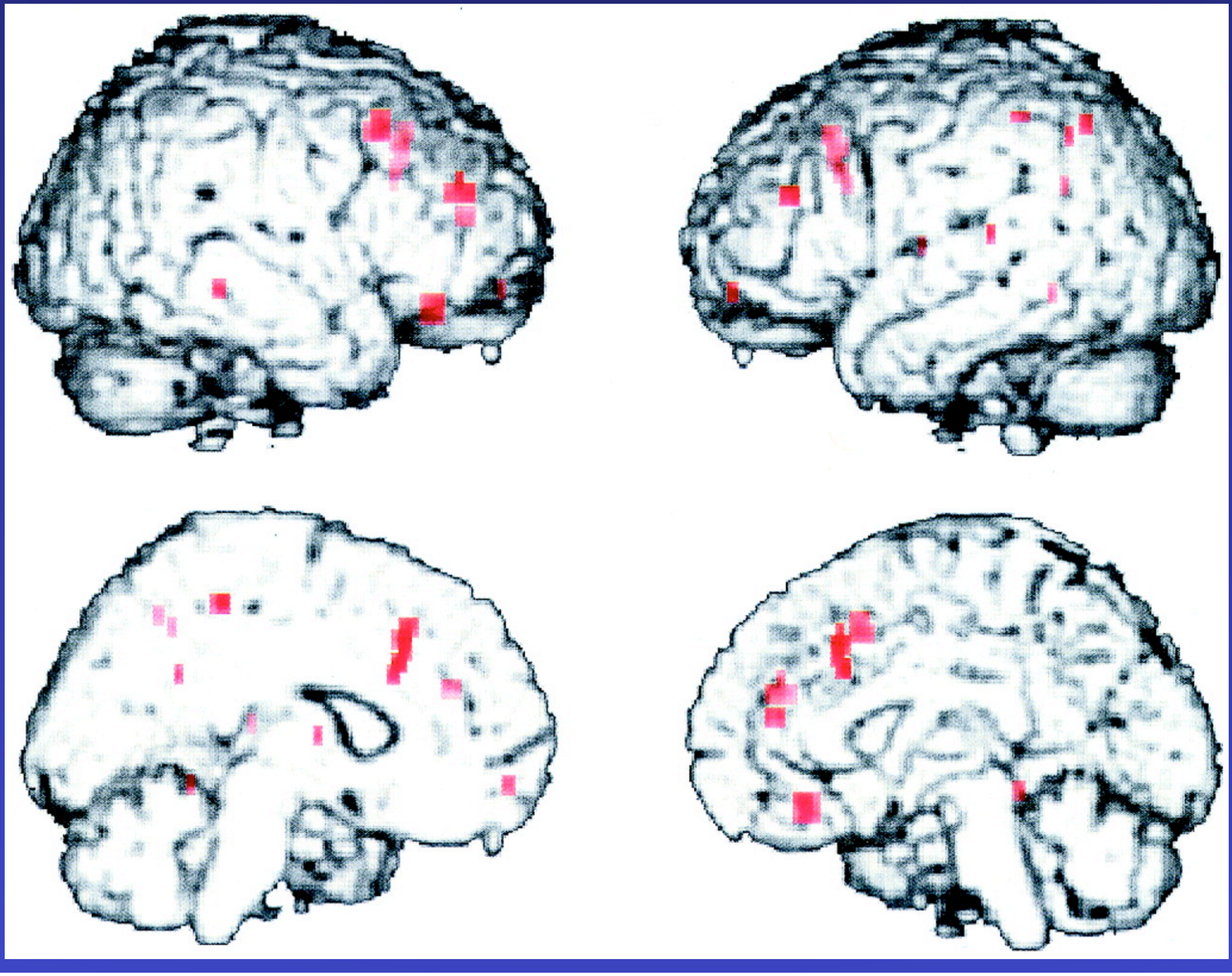
NICHD:
Peter Basser, Ph.D.
Allen Braun, M.D.

NCI:
Kathy Warren, M.D.

Papers from FMRIF



Effect of COMT genotype on fMRI activation during the two-back working memory task.



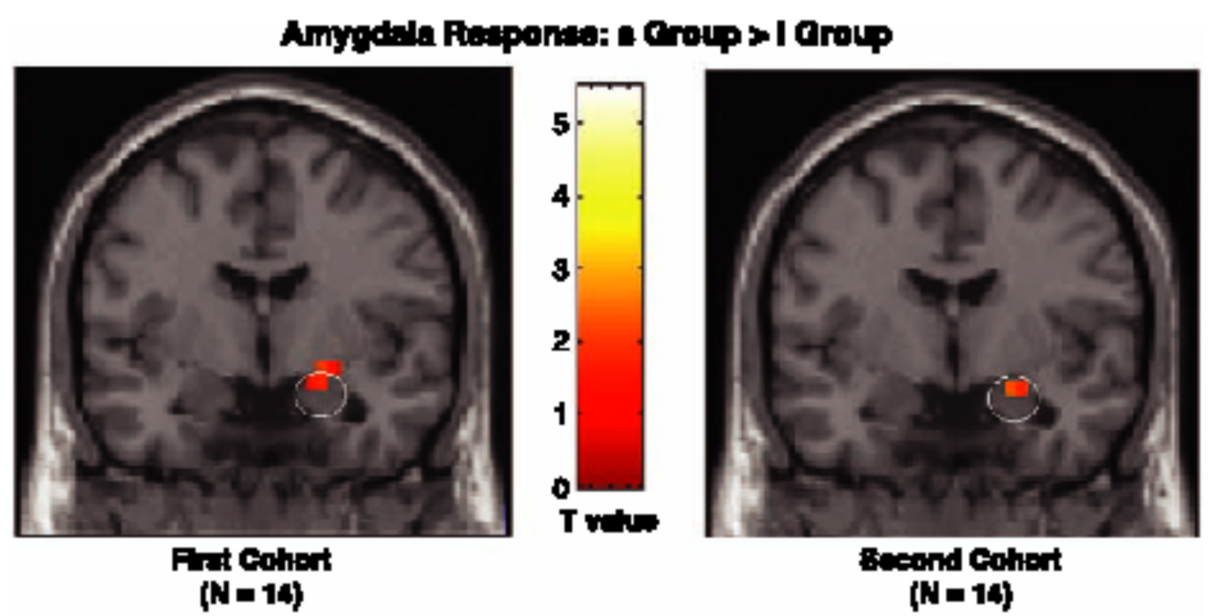
Egan M F et al. PNAS 2001;98:6917-6922

PNAS

Comparison of two groups of *normal* individuals with differences in the Serotonin Transporter Gene

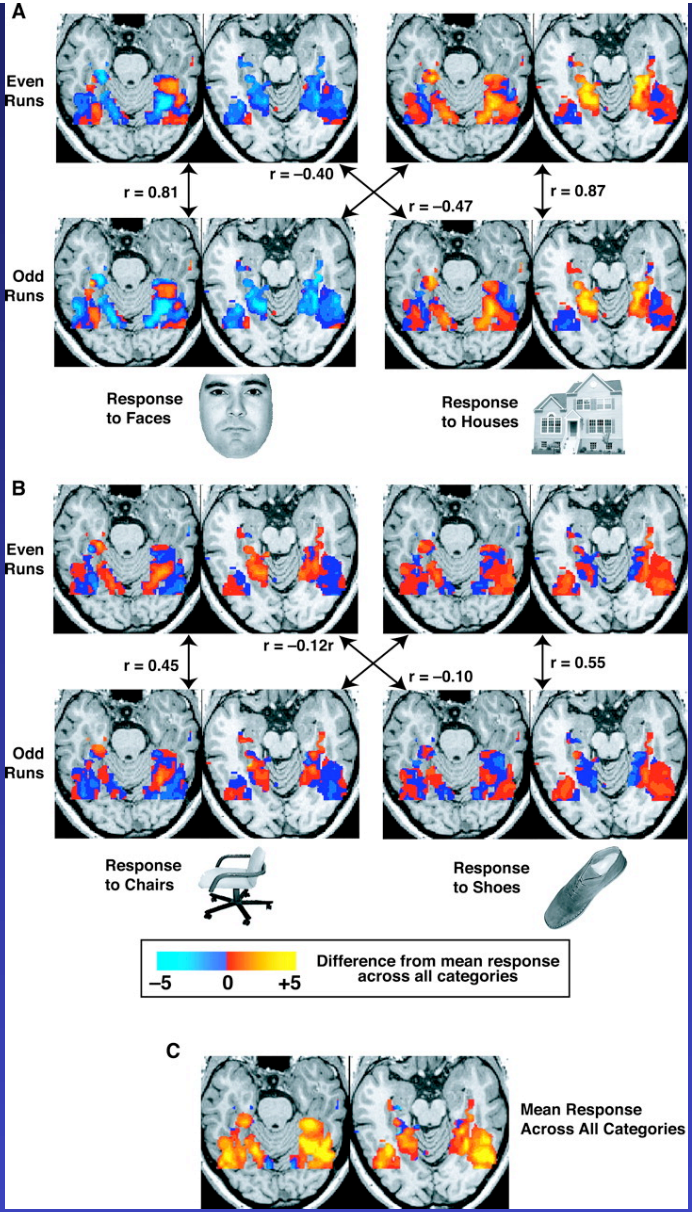
Serotonin Transporter Genetic Variation and the Response of the Human Amygdala

Ahmad R. Hariri,[1] Venkata S. Mattay,[1] Alessandro Tessitore,[1] Bhaskar Kolachana,[1] Francesco Fera,[1] David Goldman,[2] Michael F. Egan,[1] Daniel R. Weinberger[1*]



SCIENCE VOL 297 19 JULY 2002

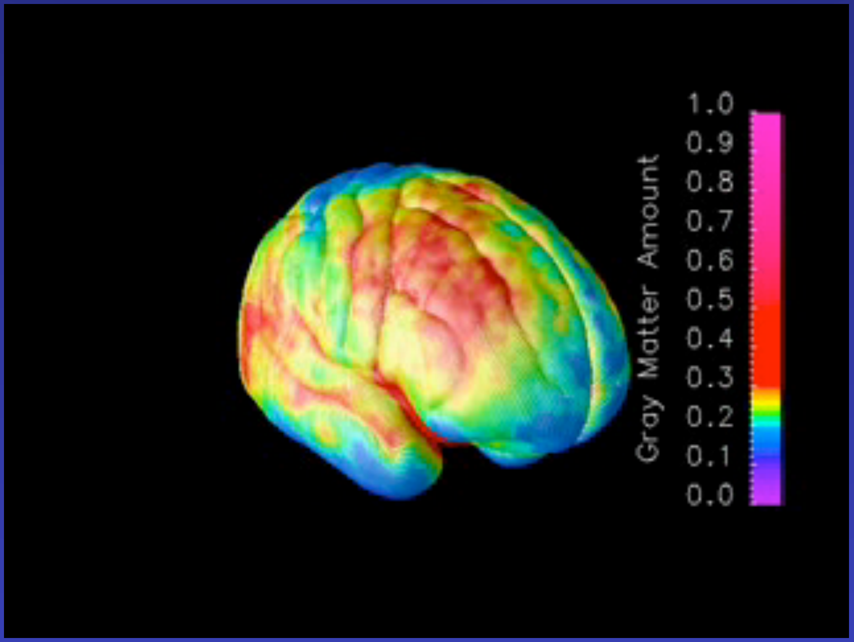
Decoding & Multivoxel Pattern Analysis



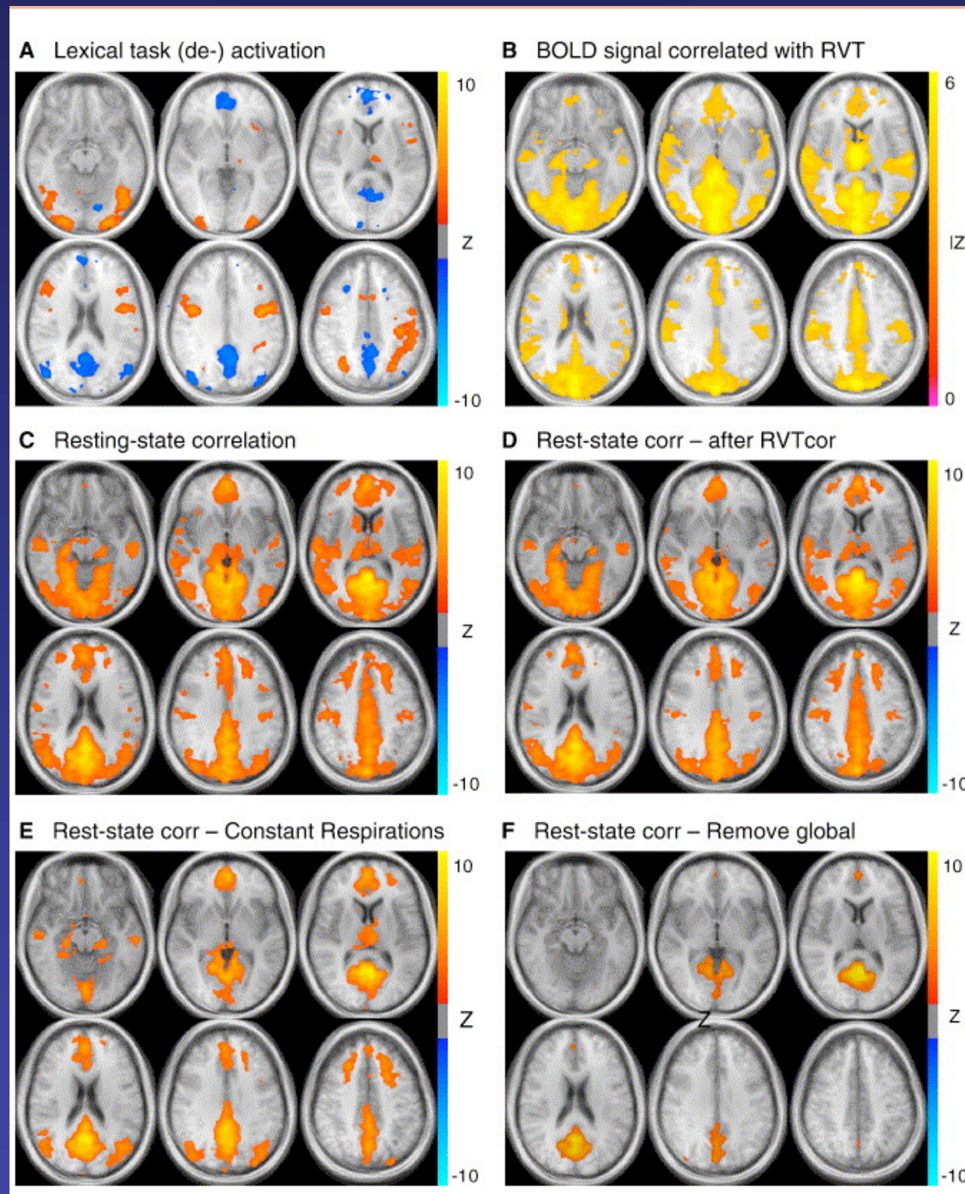
J. V. Haxby et al., Science 293, 2425 -2430 (2001)

Published by AAAS

Dynamic mapping of human cortical development during childhood through early adulthood (Gogtay et al. PNAS 2004)

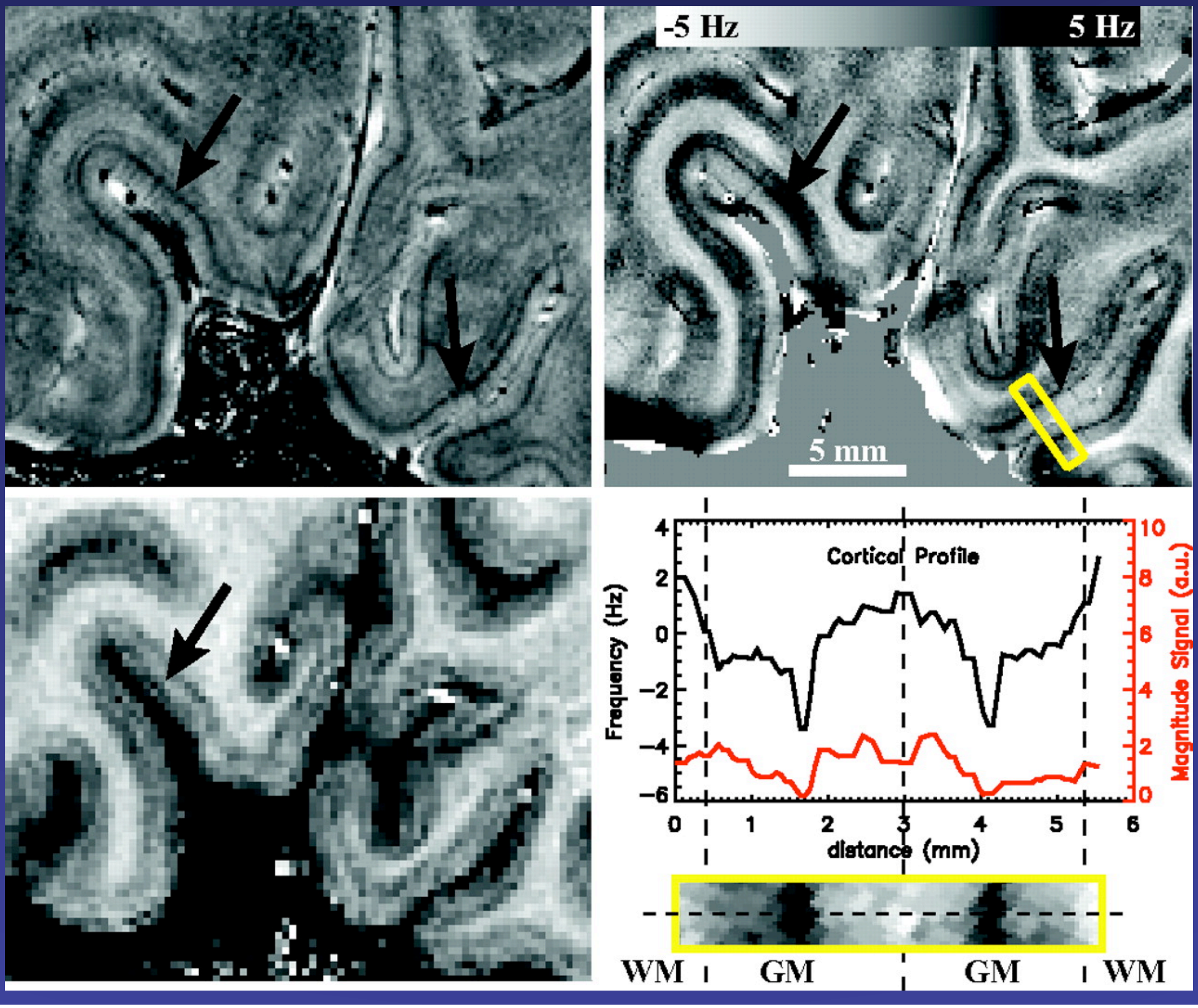


Separating respiratory-variation-related fluctuations from neuronal-activity-related fluctuations in fMRI



Birn et al, 2006

Intracortical contrast in the primary visual cortex.



Duyn J H et al. PNAS 2007;104:11796-11801

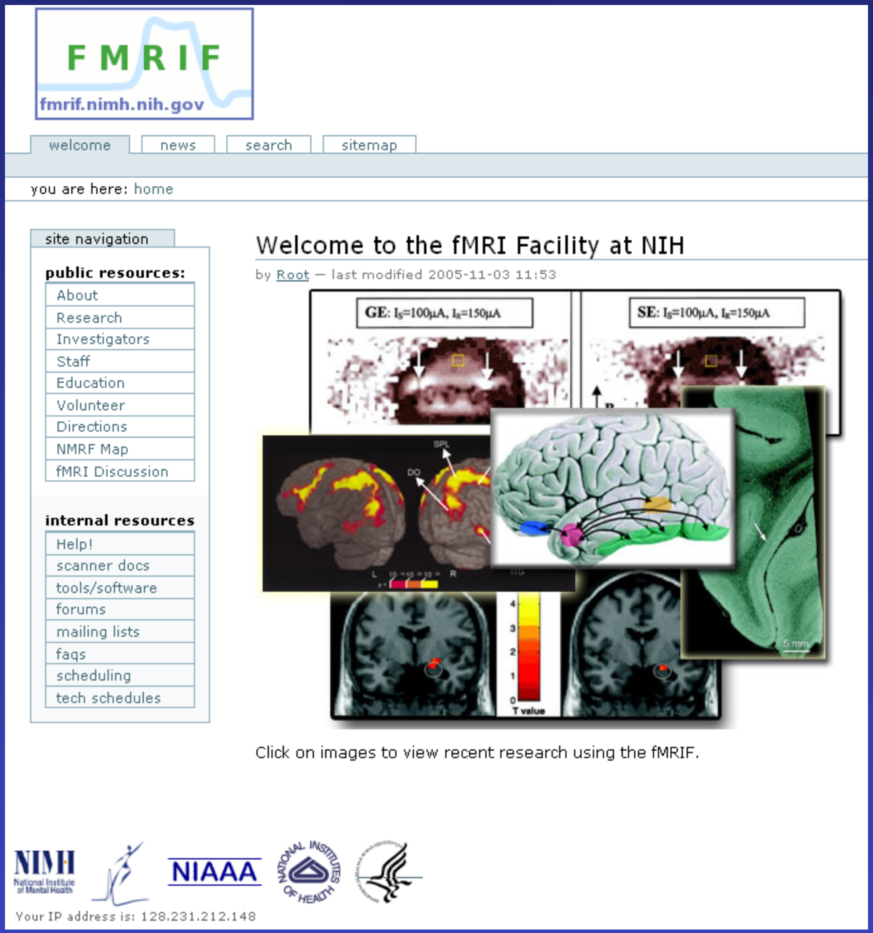
PNAS

Functional MRI Facility

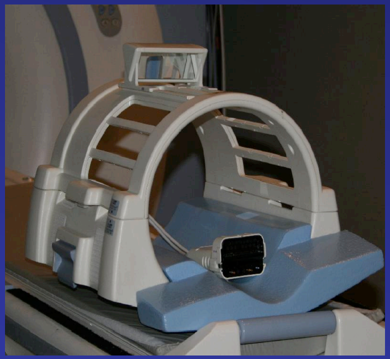
Souheil Inati	**staff scientist**
Wenming Luh	**staff scientist**
Sean Marrett	**staff scientist**
Vinai Roopchansingh	**staff scientist**
Adam Thomas	**system admin**
Ellen Condon	**technologist**
Janet Ebron	**technologist**
Kenny Kan	**technologist**
Marcela Montequin	**technologist**
Sandra Moore	**technologist**
Paula Rowser	**technologist**
Debora Tkaczyk	**technologist**
Jennifer Yeager	**technologist**
Dorian Van Tassell	**admin lab manager**

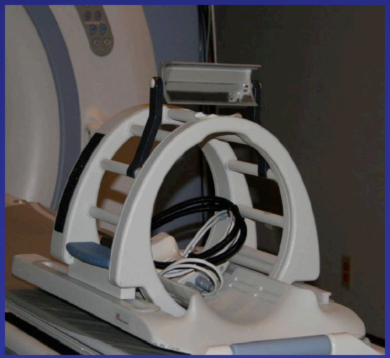
http://fmrif.nimh.nih.gov/

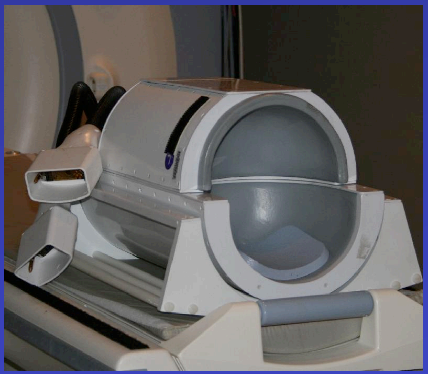
http://fmrif.nimh.nih.gov/



Basic Coil Options



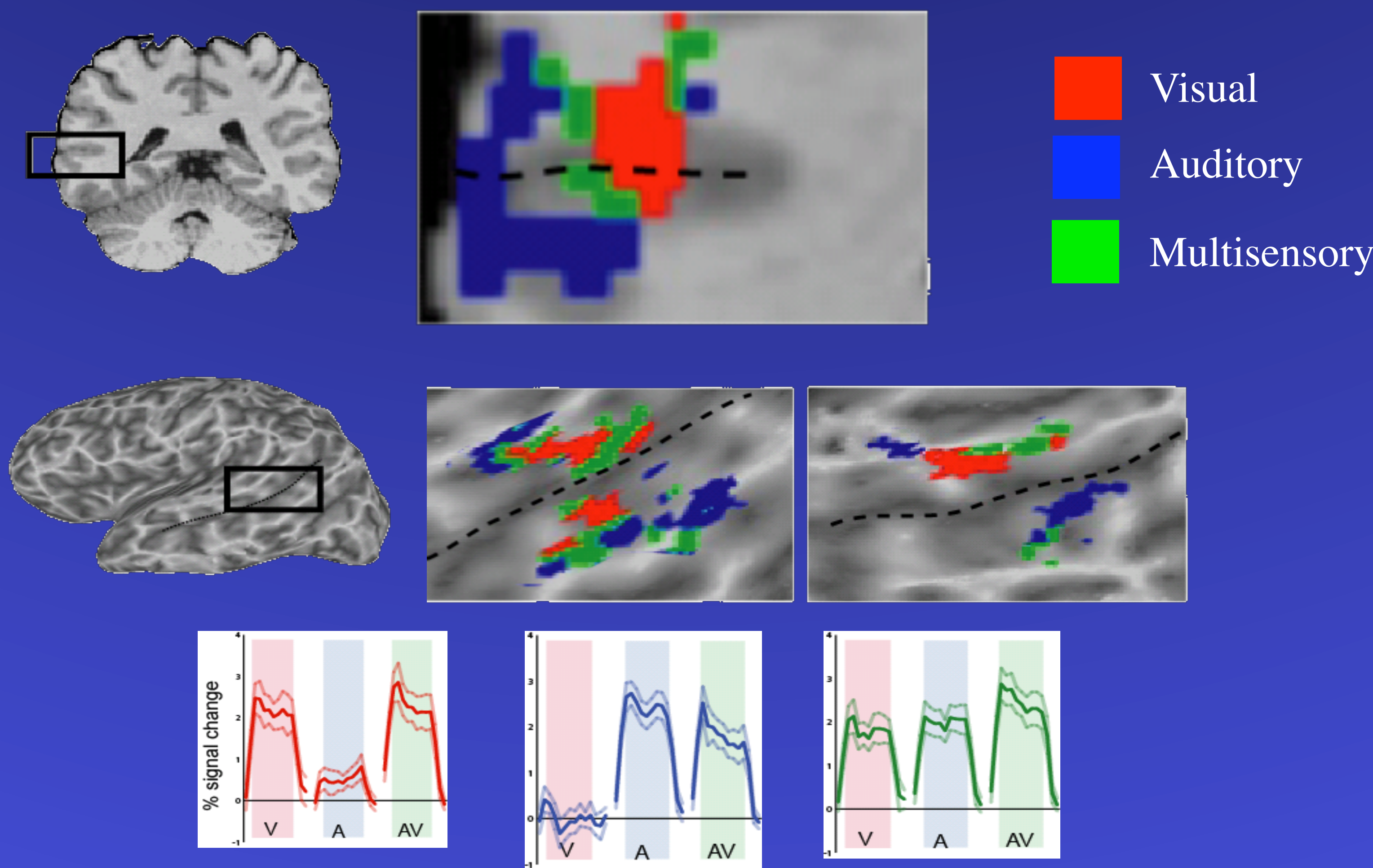




Using Parallel Imaging to Increase Spatial Resolution of FMRI

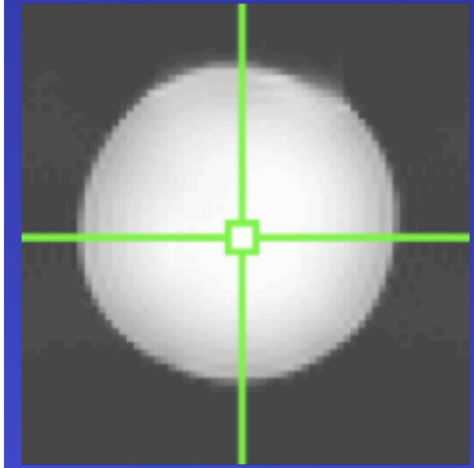
Unravelling Multi-sensory integration

M.S. Beauchamp et al.,

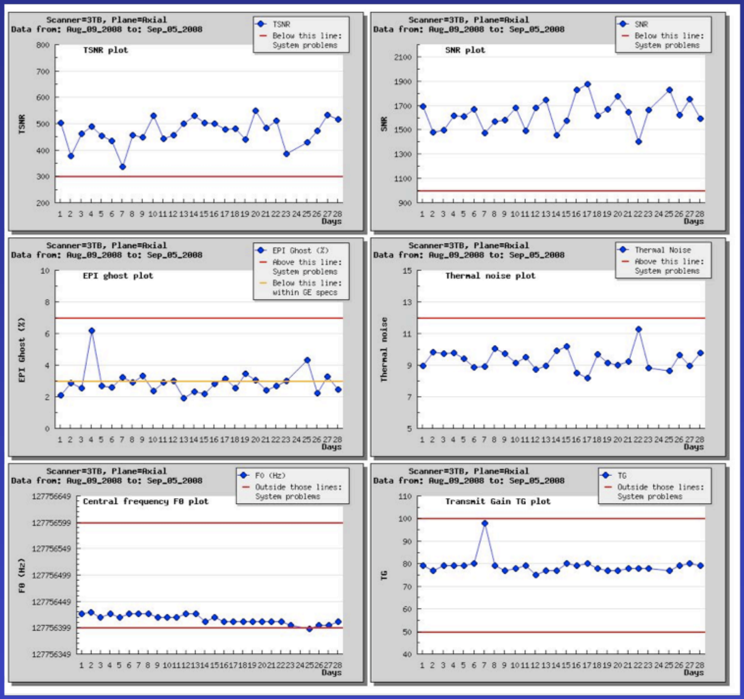


Data and Q/A

Quality Assurance (QA) Phantom

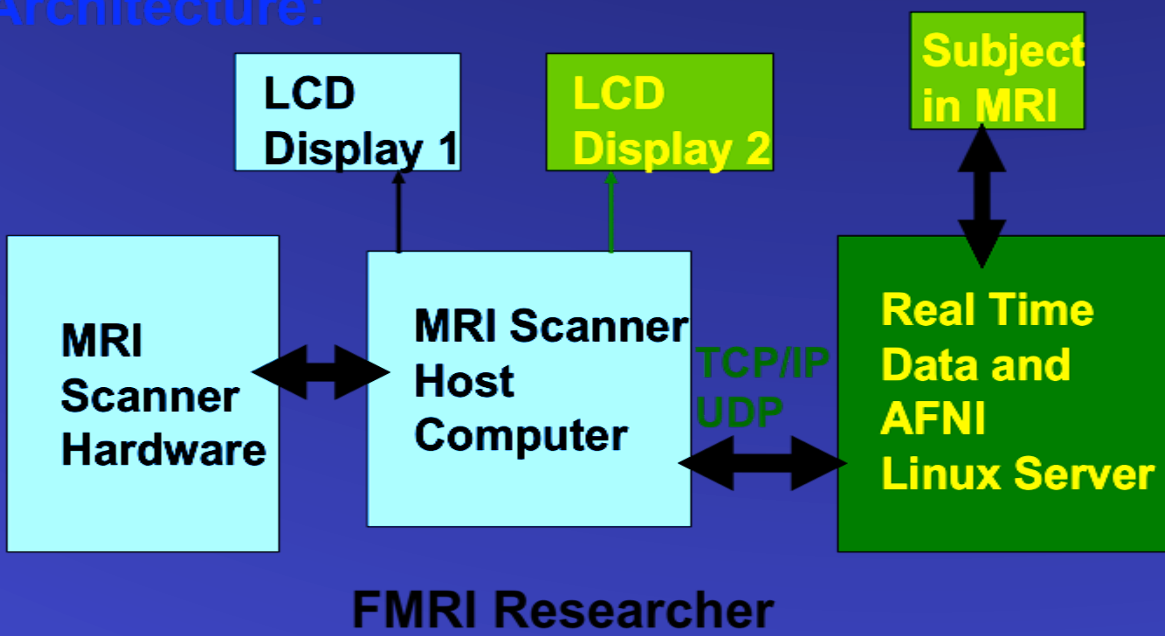


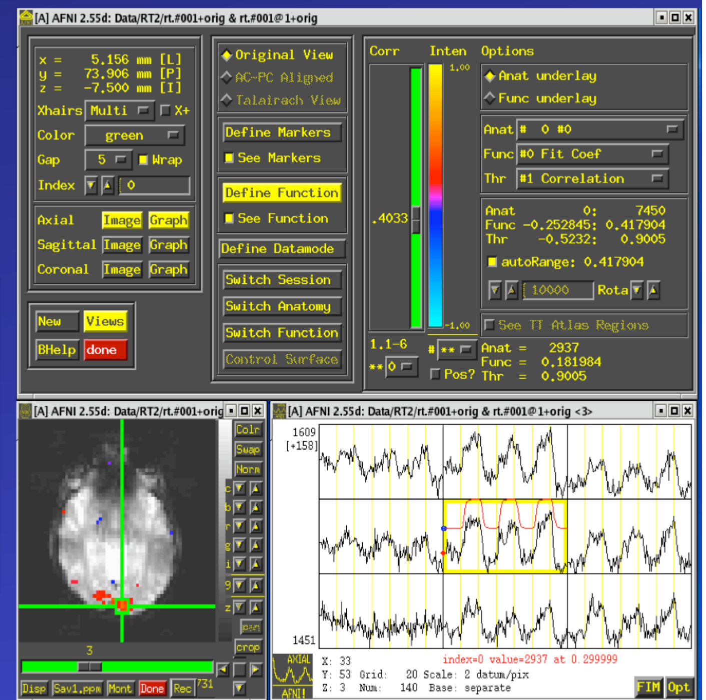
QA web interface



Real-time AFNI

Architecture:



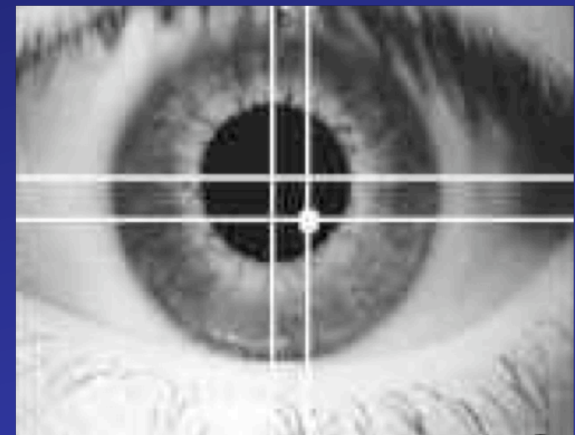


Subject Interface

Avotec video

Rear Projection

Nordic Neurolab Visual System



SensoMotoric Instr. Eye Tracking

Avotec audio

Nordic Neurolab Electrostatic Audio System

MRI-compatible miniature video camera

Hypothesis always a good thing to have – may be based on theory or functional neuroanatomy or previous neuroimaging experiments

Helpful if hypothesis suggests a specific neuroanatomical locus for change in neural activity or a network of regions?

Important to understand limitations of fMRI temporal and spatial resolution – useful to consult with FMRIF staff regarding experimental design and possibilities

Understand limitations of fMRI environment and how stimulus can be presented to subject and behavior and performance monitored.

Write protocol and submit to Scientific Review Board (SRB) and get feedback.

Get IRB approval . Submit protocol to NMRF Protocol Committee for MRI safety/sanity check (http://intranet.nmrf.nih.gov/)

Get scanner time (assigned by DIRP to individual units, sections, labs, or programs)

Ensure all research staff are trained and ,if support is needed, technologist coverage arranged.

Contact Scientific and Statistical Computing Core Facility for assistance with experimental design and planning your analysis (http://afni.nimh.nih.gov/sscc)

Additional Resources for fMRI/Research

Functional MRI Facility

In-vivo NMR Facility

Scientific Statistical Computing Core

Neurophysiological Imaging Facilty

MEG

Section on Instrumentation Core Facility

Thanks / Questions ?